Development of a radio detection array for the observation of showers induced by UHE Tau neutrinos

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The running radio-detector 21CMA is being currently adapted for ν_τ searches. 10287 antennas sit along two high altitude valleys, surrounded by mountain chains, in an exceptionally low electromagnetic noise environment. Firsts measurements obtained with the in situ, 6-antennas prototype, show the great potential for shower detection of the array. Preliminary simulations of the foreseen setup indicate that an one year exposure of $\sim 10^{13}$cm^2·s·sr for 10^{17} eV ν_τ's may be attainable using 80 dedicated antennas.

1 Introduction

The probing of the UHE component of the far away Universe relies heavily on the detection of the UHE neutrinos [1]. Unfortunately, they can be observed only indirectly, through their interaction with target nucleons. The very low interaction cross section, combined with the already small fluxes predicted [1], require detection volumes of the order of cubic kilometers.

The UHE neutrinos are produced either by the interaction of the UHE cosmic rays within their sources, or in their subsequent interactions with the background radiation fields. In both cases, tau neutrinos are much suppressed at production since they are not a decay product of the dominating pions. However, approximately equal fluxes for each flavour are expected after traveling cosmological distances to the Earth due to neutrino flavour oscillations [2,3].

There are several running experiments looking for ν_τ's, as the dedicated neutrino telescopes ANTARES [4] and IceCube [5]. The extensive air shower (EAS) detector AUGER [6] looks for ν_τ's which enter the Earth just below the horizon and produce τ leptons which can escape the Earth; subsequently, the τ's decay in flight in the atmosphere produces showers visible both in their surface array and fluorescence telescopes. The AUGER collaboration showed accumulated exposures of the order of $3 \cdot 10^{16}$ cm^2·s·sr, which allowed them to place an upper limit on the ν_τ flux approaching the theoretical predictions for the GZK neutrinos [7].

Lately, two collaborations, CODALEMA [8] and LOPES [9], showed the feasibility of radio-detection of the EAS's using an external trigger provided by ground detectors. Moreover, signal patterns obtained with a standalone, self-triggered antenna have provided convincing signatures

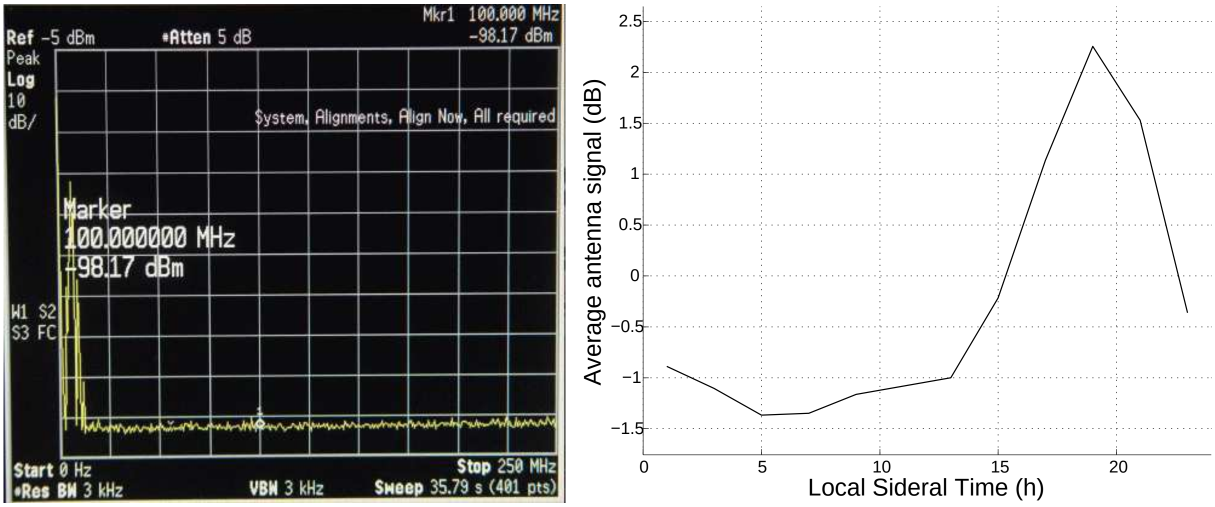

Figure 1: *Left:* average Fourier transform of the background noise for a 21CMA antenna. *Right:* antenna signal averaged over 15 hours of data taking as a function of the local sideral time, peaking to the galactic radio emission.

of EAS's [8]. An accuracy of the order of the degree was obtained by CODALEMA for the reconstruction of the arrival directions of radio transients generated by solar flares. The same reconstruction method was used for the EAS's. Under the assumption that the EAS's can be measured by standalone radio sensors with a direction accuracy of the order of the degree, we present here a proposition to look for ν_τ's using some dedicated sensors from an already existing radio array, 21CMA [10]. It is argued that the experimental site is particularly appropriate for the ν_τ detection and generally for radio detection. The status of the project is shown, as well as our expectations for the physics outreach based on preliminary simulations of the experimental setup.

2 21CMA experiment and the present setup for τ 21CMA

The 21CMA experiment is situated in the Ulastai Valley, in the Western-China province of XinJiang, at 2700 m of altitude. It is the only running experiment dedicated to re-ionisation studies. The detector consists of 10287 [50-100 MHz] log-periodic antennas, distributed over 81 groups of 127 antennas each (called in the following pods). It has two arms of 3 and 4 km length, oriented North-South and East-West respectively, which follow two almost perpendicular valleys.

On each pod, the analog signals of the 127 antennas are added and amplified by $\sim$45 dB before being sent over an optical fibre to the control room. Prior to their recording on disk, they are digitised using 81 8-bits ADCs (one for each pod), working synchronously at 200 MHz.

The first measurements performed on site showed a unique radio environment: the radio transmitters above 15 MHz are quasi-absent (Figure 1, left). The galactic plane thermal emission in the radio waveband is visible after only 15 hours of data taking (Figure 1, right), showing that the antennas have the sensitivity requiered for EAS detection.

The first phase of the project is meant to prove the principle of the EAS detection with a self-triggering array. Six antennas were positioned as seen in Figure 2, left and triggered using an amplitude threshold set at 6 times the standard deviation of the electronics noise and coincident signals on more than three antennas. A triangulation reconstruction leads to the signal origin.

The time calibration of the setup was checked by reconstructing a nearby radio source of known position. The dispersion of the reconstructed position of the source (Figure 2, right), is compatible with a time resolution of an antenna of few ns.

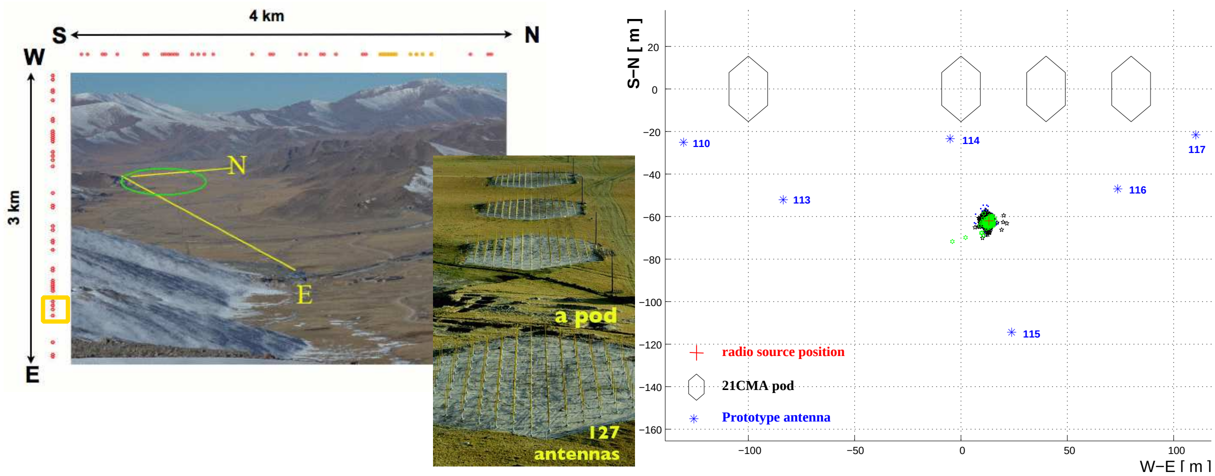

Figure 2: *Left:* the positions of the 81 pods in the two valley are shown (the red dots). The 6 pods housing our supplementary antennas are highlighted by the yellow rectangle. *Middle:* a close view of the pods. *Right:* the position of the six antennas (blue stars), the position of the car used as radio source (red cross) and the reconstructed origin of the signal (green and black points).

3 Simulation Chain

The detection principle for ν_τ's at 21 CMA is the following: a UHE, almost horizontal ν_τ, interacts with the mountains surrounding the antennas. The produced τ can escape the mountains and if it decays within the valley it produces a shower which can be seen by the antennas. The mountains act also as shielding against the EAS's due to the cosmic ray interactions in the atmosphere. An angular resolution of $\sim$degree should prevent contamination from downgoing CR EAS's.

Starting with a diffuse neutrino flux, the τ flux will depend on the depth of matter crossed, which is calculated from satellite data[11]. The ν_τ-nucleon interaction is simulated with Pythia[12]. The τ propagation assumes continuous losses[14] and its decay is simulated with the TAUOLA package[13]. The radio signal is generated following the longitudinal and radial profiles of the shower and it has an exponential fall with the distance[15]. The typical electronics noise is simulated and the trigger is defined by three or four coincident antennas. With a complete detector with 81 antennas (one per pod) the expected effective surface at the trigger level is shown in Figure 3, left, as function of the incoming ν_τ angle with the local vertical for an energy of 10^{19} GeV. It reaches $3.5 \cdot 10^3 \mathrm{m}^2$ for horizontal ν_τ's in the case of four coincident antennas. On the right of the same figure, the achievable exposure in one year of data taking is shown as function of the incident neutrino energy.

4 Conclusion

The project of using the running 21CMA radio detector for $\nu_\tau$searches started in June 2008 and the first results are very encouraging. The radio environment is ideal: almost no terrestrial noise, the measurement of the radio signal from the galactic plane offers a reliable calibration of the antenna sensitivity. A lot of effort is ongoing for the time inter-calibration of the prototype using known radio sources. If clear measurements of the EAS will be available before summer 2009, the prototype will be then upgraded to the full 81 antennas. Simulation studies show that the 21CMA layout is very efficient for the detection of ν_τ's with energies between 10^{16}- 10^{19} eV, though further up-scaling is necessary for it to be competitive with existing detectors.

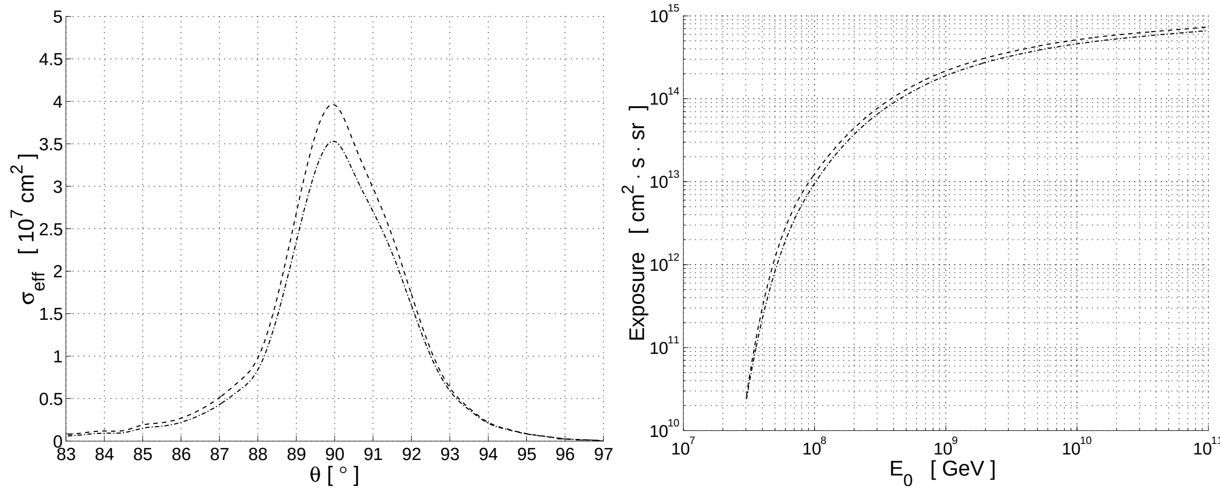

Figure 3: *Left:* effective surface at the trigger level as a function of the incoming $\nu_\tau$angle with the local vertical for 10^{19} GeV ν_τ. *Right:* expected exposure in one year of data taking as function of the incident neutrino energy. The different curves correspond to triggers requiring 3 or 4 coincident antennas.

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